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Amphibian & Reptile Conservation
13(2) [Special Section]: 68–81 (e197).

Value of forest remnants for montane amphibians on the livestock grazed Mount Mbam, Cameroon

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***Abstract.*—Habitat loss and degradation are the primary threats to biodiversity, especially for amphibians. In the Highlands of Cameroon, knowledge on the impacts of different forms of habitat loss, such as livestock management, is restricted to anecdotal reports. This study investigated the impact of forest fragmentation, driven primarily by livestock grazing, on the amphibian assemblage on Mount Mbam, West Region, Cameroon. Stratified, multi-season surveys over two years recorded the abundance and community composition of anuran species. Based on the revised inventory of amphibians the proportion of threatened species on Mount Mbam was calculated at 23.52%. A small population of *Phrynobatrachus steindachneri* was found to occur despite having completely disappeared on other mountains in its distribution range. One species known to the mountain, *Cardioglossa schioetzi*, was not found during the surveys. The remaining forest patches were found to be significant habitat for several species endemic to the mountains of Cameroon-Nigeria. The savanna, likely expanded by livestock grazing, held numerous reed frog species that likely benefit from forest loss, especially in low- to mid-range elevations. The observed relationship between land-use and amphibians on this mountain indicates that the ongoing conversion of forest to pasture threatens remaining montane endemic anuran species, with conservation planning and action now necessary.**

Keywords. Africa, endemic, frog, grassland, habitat fragmentation, habitat loss

Citation: Tchassem Fokoua AM, Gonwouo LN, Tamesse JL, Doherty-Bone TM. 2019. Value of forest remnants for montane amphibians on the livestock grazed Mount Mbam, Cameroon. *Amphibian & Reptile Conservation* 13(2) [Special Section]: 68–81 (e197).

Received: 9 March 2019; **Accepted:** 15 August 2019; **Published:** 7 November 2019

Introduction

Vertebrate animal taxa are disappearing worldwide at high rates; especially amphibians, a group which has a high proportion of threatened species (Stuart et al. 2004; Beebee and Griffiths 2005). The five main factors believed to be driving global amphibian declines are the introduction of alien species, habitat alteration, over-exploitation, global change, and infectious diseases (Collins and Storfer 2003). The most severe stressor is physical habitat degradation and destruction (Noss et al. 1997; Stuart et al. 2006). These factors have been found in combination with enigmatic amphibian declines, occurring particularly at localities above 400 m asl in the Americas, Europe, and Australia (Pounds et al. 2006; Vences and Kolher 2008). However, studies on amphibians in African mountains are limited to a handful of sites, although recent findings have shown declines in the Cameroonian mountains that are either enigmatic (possibly associated with chytridiomycosis) or linked to habitat loss (Hirschfeld et al. 2016; Tchassem et al., in press).

Cameroon is one of the most diverse countries in terms of amphibian species, and it is home to about 4% of the world's known species of frogs (IUCN 2017). The Bamenda Highlands form the northern portion of the Highlands of Cameroon that includes Mount Mbam. Some species known to occur in Mount Mbam are only known from one or a few mountains, including some species classified as Vulnerable or Endangered in the IUCN Red List. This mountain has been studied less extensively than many others, but its study should be a priority given the community level amphibian declines in neighboring mountains (Hirschfeld et al. 2016; Tchassem et al., in press), where the causes remain uncertain as to whether they are habitat driven or the result to other factors such as the chtyrid fungus (*Batrochochytrium dendrobatidis* [*Bd*]). The impacts of environmental change on the Cameroon mountains are still unclear, especially regarding habitat loss, due to limited studies across Sub-Saharan Africa in

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general (Buckley and Jetz 2007).

Deforestation rates are exceptionally high across West and Central Africa (Hansen et al. 2013). In the biodiverse highlands of Cameroon and Nigeria (Bergl et al. 2007), forest loss is driven by a combination of clearance for cultivation, overexploitation of wood fuel, and incursions by livestock (Chapman et al. 2004). The impact of this loss of forest on amphibians has so far been assumed to be the loss of montane endemic species, but the specific factors driving the declines that are associated with forest loss have not been determined. This uncertainty includes the potentially differential impacts of livestock grazing versus cultivation, for example, with potential exacerbation by agrochemicals (Tchassem et al., in press). This scenario is especially applicable to the degradation of natural habitats in the Bamenda Highlands of Cameroon, that include Mounts Oku, Bamboutos, Lefo, and Mbam, which share similar montane endemic species (Cheek et al. 2000; Doherty-Bone and Gvoždík 2017). Montane forest cover has decreased dramatically during the 20th and 21st centuries; with remaining forests becoming highly fragmented (Abbot et al. 2001; Doherty-Bone and Gvoždík 2017). Agrochemical pollution and grazing have not been systematically studied in this area, and since they often occur simultaneously, differentiating the impacts of each stressor is difficult (Tchassem et al., in press).

Mount Mbam has historically been appraised for amphibian diversity, with several montane endemic species identified in the 1970s, such as Perret's Egg Frog (*Leptodatylodon perreti*) and Steindachner's Puddle Frog (*Phrynobatrachus steindachneri*) [Amiet 1971, 1973, 1976]. Despite this work, the mountain has no official protection, and deforestation remains unchecked. Unlike other mountains in the Bamenda Highlands, Mount Mbam does not have considerable cultivation of crops in contrast to its widespread livestock grazing. This study focuses on Mount Mbam to assess the status of the amphibian community and threats from encroachment by livestock grazing. Grazed areas and remnant forests were surveyed, incorporating an elevational gradient, to determine: (1) whether the diversity of amphibians has been altered compared to historical records; and (2) which amphibian species are excluded from the grazed areas compared to the gallery forest.

Materials and Methods

Study area. Mount Mbam (sometimes known as the Mbam Hill Forest), is a calcareous massif located near the town of Foumban in the West Region of Cameroon (Fig. 1, 05°57'N, 10°44'E). It rises from the savanna plains at 1,000 m to a summit of 2,100 m asl. The vegetation of the mountain is transitional between montane savanna grassland mixed with patches of gallery forest (Fotso et al. 2001; Fig. 2). The forest patches are dominated by *Albizia gummifera, Polyscias fulva,* and *Schefflera mannii* (Fotso et al. 2001). Human communities living around and using the mountain include the Banso'o, Haoussa, and Fulani peoples. Livestock grazing is predominately practiced by the Fulani community, who are semi-nomadic, and concentrated at higher elevations where they live for nine months during the year, from April to December. During January to March (the dry season), these cattle herders move down the mountain to other pastures at lower altitudes.

Study design. To ensure a representative appraisal of diversity, the Mount Mbam amphibian fauna was surveyed over a period of two years, between 2014 and 2016. Field surveys were deployed, with all sample sites visited at least three times. During diurnal and nocturnal visual encounter surveys (VES) with a total duration of 96 surveyor-hours across each land use type were used to quantitatively sample fossorial, arboreal, and water-associated amphibian species (Rödel and Ernst 2004). Nocturnal acoustic encounter surveys were also used to detect animals. Opportunistic sampling was made for all taxa throughout the survey to enable additions to the updated inventory. All sampling sites were characterized with the following environmental data: altitude and coordinates (recorded with a Garmin® GPS exter 90), presence of potential breeding sites, regime of disturbance, and vegetation structure. The vegetation was determined at three strata (canopy cover, shrubs, and understory). Surveys were stratified between gallery forest (the only remnant forest on the mountain) and grassland (primarily grazed by livestock). Surveys involved searching of microhabitats, such as lifting rocks and logs, peeling away bark from trees, moving fallen debris, and inspecting tree stems during daytime (07:00–12:00 h) and night time (19:00–00:00 h) along streams, ponds, and the surrounding vegetation (Crump and Scott 1994; Rödel and Ernst 2004). Amphibians were captured by hand, and then identified and released where they were found. However, a subset of 1–3 individuals of each species, and specimens difficult to identify in the field, were euthanized using an overdose of MS-222 or chlorobutanol solution and preserved in 75% ethanol. These specimens have been deposited in the University of Yaoundé I, Laboratory of Zoology. For species identification, original descriptions and derived literature were used (Perret 1966; Amiet 1977, 1980, 2012; Schiøtz 1999).

Data Analysis. The proportion of threatened species in the total amphibian species inventory for Mount Mbam (both historical and contemporary species observed) was calculated following Böhm et al. (2013). All other analyses were performed with the statistical package R version 3.3.2 (R Core Team 2016). Inventory completeness was assessed using an incidence-based

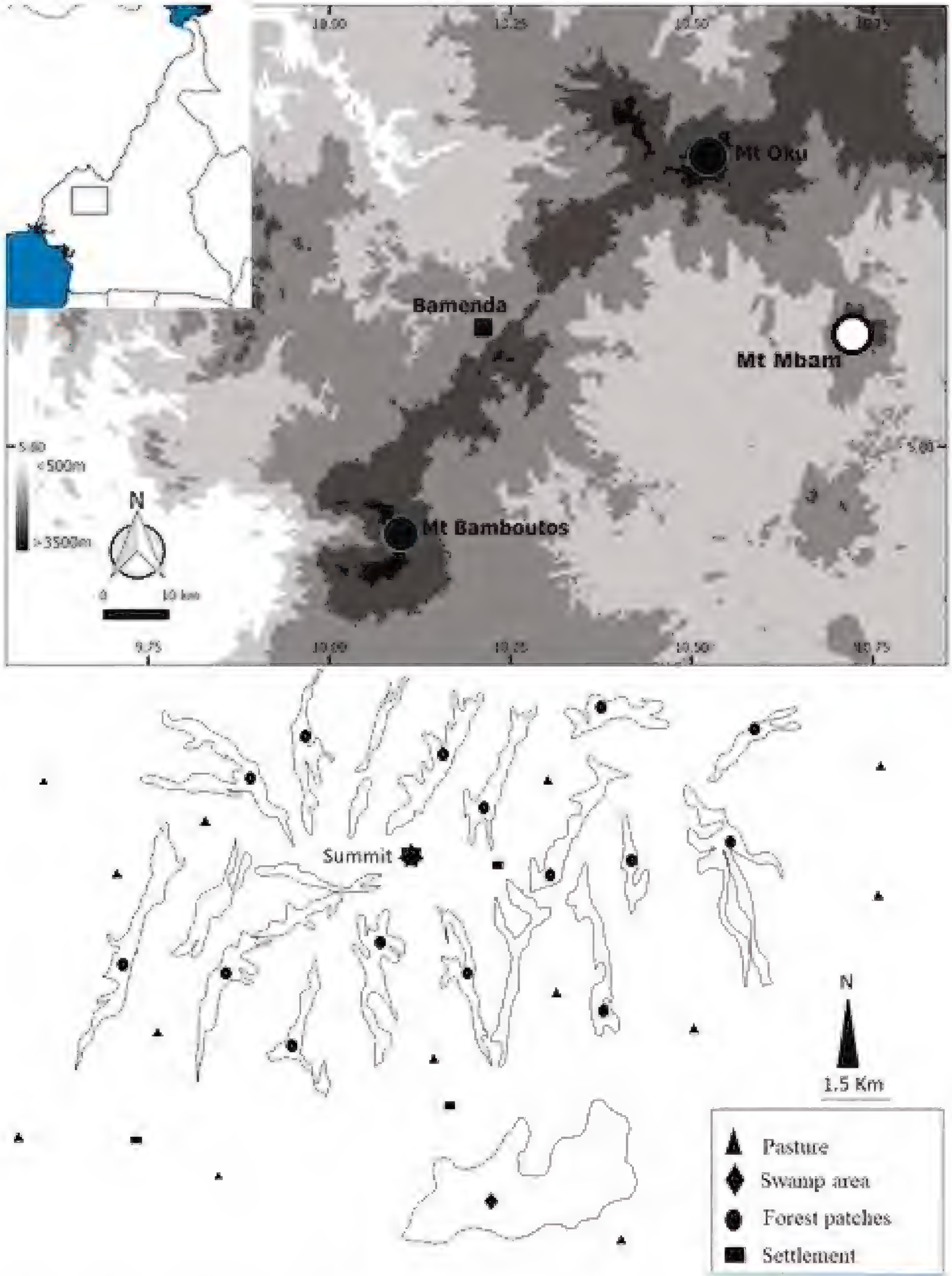

Fig. 1. Maps showing (top) the topography of the Bamenda Highlands, white circle showing Mount Mbam in the West Region of Cameroon; and (bottom) the layout of sample sites on Mount Mbam.

estimator with the package BiodiversityR (Colwell and Coddington 1994). To compare the amphibian community composition between habitat types, PERMANOVA analysis (formula: Adonis, library: vegan) was used to test the significance of the Bray-Curtis dissimilarity based on 999 permutations (Anderson 2001; Riemann et al. 2017). Amphibian abundance data transformed by square root were subjected to ordination analysis using non-metric scale (NMDS) plots of Bray-Curtis dissimilarity (formula: metaMDS, library: vegan) to view the dispersion of similarities. The species contribution to differences between different types of habitats was evaluated by SIMPER analysis (Clarke 1993). The influence of habitat (forest patches, pasture-grassland) on species abundance was evaluated using Generalized Linear Models (GLM, formula: glm, data family: poisson) [O'Hara and Kotze 2010]. Various parameters such as season, year, and elevation were incorporated into the GLMs to assess potential confounding factors against the response variables (abundance of frogs). GLMs were restricted to species for which a minimum of five individuals were recorded in the surveys. Information criterion analysis was then applied to the GLMs, in which derived Akaike's Information Criteria were used to assess the best performing model based on incorporation of these potentially competing explanatory factors (Mazerolle 2006).

Results

The surveys revealed 17 anuran species of seven genera among 225 individuals (Table 2). Based on these and

Fig. 2. Montane habitats of amphibian species observed in recent surveys of Mount Mbam, West-Region, Cameroon: a) gallery forest during the rainy season; b): gallery forest during the dry season after a bushfire; c) savanna area transformed by overgrazing; and d): effects of bushfire started for pasture on the same site during the dry season.

historical records, the proportion of threatened species on Mount Mbam is estimated at 23.52%. However, the species accumulation curve over the survey periods did show a plateau, indicating the discovery of more species with further searching is unlikely (Fig. 3). In comparison to historical records, one species missing from the contemporary surveys was *Cardioglossa schioetzi* (Table 1). The Puddle Frog, *Phrynobatrachus steindachneri*, was found, but only four sub-adult individuals were observed over the two years. Species new to the historical inventory included the Rocket Frog *Ptychadena mascareniensis* "D" (Zimkus et al. 2016) and the Clawed Frog *Xenopus* cf. *eysoole* (Fig. 4m). The latter species was found as high as 1,600 m asl in stagnant water bodies (including wells) that were heavily frequented by local people and livestock.

Community structure (measured by Bray-Curtis dissimilarity) between the two habitat types was significantly different (PERMANOVA: p = 0.01, Fig. 5). Most amphibian species were found in savanna (13 species, 76.47% of individual frogs), with seven species (16% of individuals) found in forest (Table 2). Gallery forests were dominated by species of Arthroleptidae, notably *Astylosternus montanus*, *L. perreti*, and *A. rheophilus*, which shared the same breeding sites (streams) [Table 3]. *Leptopelis notatus* was more dominant in forests at lower elevations (1,307–1,340 m). The only anurans of Phryobatrachidae on the mountain were *P. steindachneri* restricted to forests at 1,400–1,800 m (Tables 2–3). The only Hyperoliidae found in the forests were a singleton of *Afrixalus* aff. *fulvovittatus* (at 1,342 m) and two individuals of *Hyperolius igbettensis* (at 1,342–1,684 m), though they likely spilled over from the grassland areas.

Within derived savanna (i.e., savanna created by cattle grazing and fire) Hyperoliidae (43.55% of all individual frogs) was the most dominant group, represented primarily below 1,500 m by *Hyperolius concolor*, *H. balfouri*, *H. tuberculatus*, *H. igbettensis*, *H. nitidulus, H. cinnamomeoventris,* and *A.* aff. *fulvovittatus* (Tables 2–3). This family was followed by Pipidae (25.8% of individuals, represented by *X.* cf. *eysoole* only), Arthroleptidae (7% for *L. notatus*, *L. nordequatorialis*, as well as a minority of five individual *A. montanus*), Ptychadenidae (5.8%, represented by *P. mascareniensis* "D" only), Bufonidae (2.2% for *Sclerophrys maculata* only), and Dicroglossidae (2.2% for *Hoplobatrachus occipitalis* only). Four species occurred in both habitats: *A.* aff. *fulvovittatus*, *A. montanus*,

Table 1. An updated amphibian species inventory for Mount Mbam, Cameroon.

Anuran taxa	Species authority	Global IUCN status	Endemicity	References
Arthroleptidae				
Astylosternus montanus	Amiet, 1978	LC	CNH	Amiet 1978; present study
Astylosternus rheophilus	Amiet, 1977	VU	CNH	Amiet 1977; Hirschfeld et al. 2016; present study
Cardioglossa schioetzi	Amiet, 1982	VU	CNH	Amiet 1982; Schiøtz 2004
Leptodactylodon perreti	Amiet, 1971	EN	BamH	Amiet 1980; present study
Leptopelis nordequatorialis	Perret, 1966	LC	CNH	Perret 1966; Amiet 1971, 1974, 1980; Gartshore 1986; present study
Leptopelis notatus	(Peters, 1875)	LC	S-Sa	Boulenger 1906; Nieden 1909; Goin 1961; present study
Bufonidae				
Sclerophrys maculata	(Hallowell, 1854)	LC	PanAfr	Hirschfeld et al. 2016; present study
Hoplobatrachus occipitalis	Günther, 1858	LC	S-Sa	present study
Hyperolidae				
Afrixalus aff. *fulvovittatus*	Pickersgill, 2007	LC	S-Sa	Perret 1976; present study
Hyperolius balfouri	Werner, 1907	LC	S-Sa	Werner 1908; Scortecci 1943; Monard, 1951; present study
Hyperolius cf. *cinnamomeoventris*	Bocage, 1866	LC	S-Sa	Inger 1968; Largen and Dowsett-Lemaire 1991; Schiøtz 1999; present study
Hyperolius igbettensis	Mertens, 1940	LC	S-Sa	Schiøtz 1963; present study
Hyperolius nitidulus	Peters, 1875	LC	S-Sa	Perret 1966; present study
Hyperolius tuberculatus	Mocquard, 1897	LC	S-Sa	present study
Pipidae				
Xenopus cf. *eysoole*	Evans et al. 2015			present study
Phrynobatrachidae				
Phrynobatrachus steindachneri	Neiden, 1910	VU	CNH	Mertens 1968; Hirschfeld et al. 2016
Ptychadenidae				
Ptychadena mascareniensis "D"	Zimkus et al. 2017	LC	S-Sa	present study

Endemicity codes for species limited to: S-Sa - sub-Saharan Africa; C.W.A+Ng - Central and West African countries and Nigeria; BamH – just the Bamenda Highlands of Cameroon that includes Mount Mbam; CNH: just the Bamenda Highlands of Cameroon and Nigeria.

H. igbettensis, and *L. notatus*.

Species represented by at least five individuals, regardless of habitat type, varied with the strength of the models in relation to habitat type. Species usually associated with forest had better fitted models with habitat (ΔAIC 0–7) and significant *p*-values, notably *Astylosternus* sp. and *L. perreti*, as well as some savanna species such as *P. mascariensis* "D," *H. nititdulus,* and *H. tuberculatus* (Table 4). Species associated with savanna (*Afrixalus,* some *Hyperolius* sp., and *S. maculata*) and *L. notatus*, however, did not show statistically significant or well fitted models with habitat as a fixed variable (Table 4). Habitat*elevation and season*elevation both provided the best fitted models (the lowest AIC) for *A. rheophilus*, with a ΔAIC of seven from the inclusion of habitat alone or from the inclusion of habitat*elevation*season. Habitat is a major contributor for the best fitted models for the species *A. montanus* (habitat*year), *L. notatus* (habitat*elevation), and *P. mascareniensis* "D" (habitat*season) [Table 4]. Year of survey did have an influence over the fit of the models, with the exceptions of *H. cinnamomeoventris*, *P. mascareniensis,* and *S. maculata*, manifest by all three having fewer records for the year 2016. For the remaining species, the lack of an influence of year indicates population stability in this two-year time period on the mountain.

Discussion

This study quantitatively assessed the status and habitat use of amphibians on Mount Mbam, Cameroon, in relation to land use. The species inventory of the amphibians of the mountain was updated, revealing little additional diversity recorded for the Mbam massif so far, beyond more lowland-adapted species. The stratified survey enabled better understanding of the habitat requirements of numerous amphibian species, especially montane species with restricted ranges. Species composition varied considerably between montane savanna and forest habitats. With a higher elevation, the forest was generally found to have fewer species, but with considerably more numerous montane endemic species. There were clear instances of spillover from one habitat to another, typified by the occurrences of a minority of species in one habitat compared to the habitat in which they are numerically

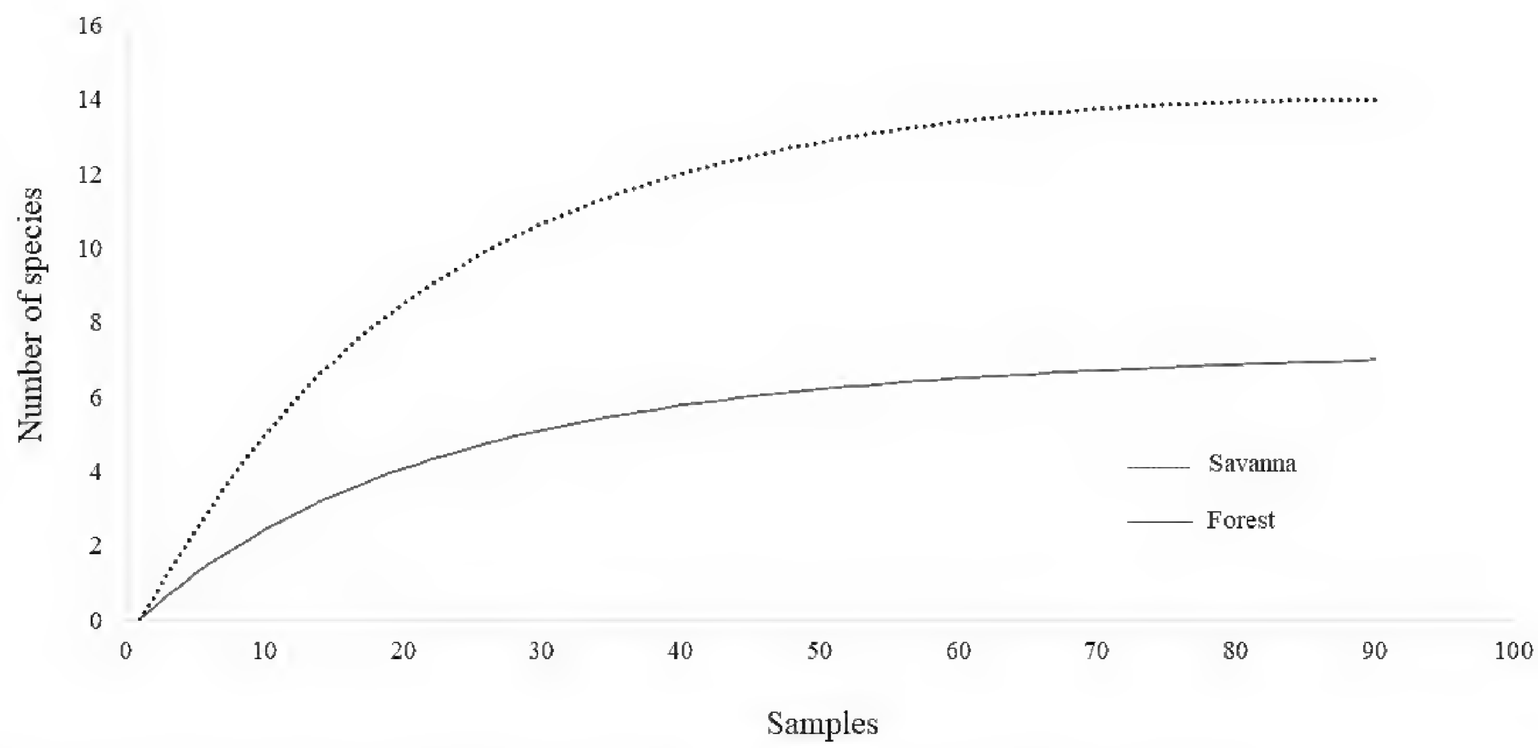

Fig. 3. Species accumulation curves of Mount Mbam by land use based on contemporary records.

dominant.

Compared to nearby mountains such as Oku or Bamboutos, Mount Mbam has a more diverse community of hyperoliids, likely due to a greater area of the mountain consisting of lower elevations. This is in contrast to mountains such as Bamboutos, where agrochemicals are widely used. It is notable that the genera *Arthroleptis* and *Kassina* were not observed in either historical or contemporary surveys, and the explanation for their absence is unclear. Montane endemic species known to Mounts Lefo, Oku, and Bamboutos, including *Cardioglossa oreas*, *C. pulchra*, and *Astylosternus ranoides*, were not found on Mbam. This is despite other species such as *Leptodactylodon perreti* and *A. rheophilus* occurring on this mountain, and the fact that these absent species do have elevational ranges corresponding to that of Mt. Mbam. This suggests the possibilities that they are either: (i) locally extinct through human land use practices or climate change that pre-date the first surveys of the mountain in the 1960s, or (ii) that the mountain is too small and low in elevation for viable populations of the higher montane endemic frog species to persist.

Despite its disappearances on Mount Oku in the North West Region and Mount Bamboutos in the West Region (Doherty-Bone and Gvoždík 2017; Tchassem et al., in press), *P. steindachneri* was observed during the recent field surveys. This taxon is part of a species complex that could possibly also include *P. jimzimkusi* (Zimkus and Gvoždík 2013). *Cardioglossa schioetzi* was not observed in this study, and it was also not found on Mount Oku in recent years, as with certain other species of *Cardioglossa, Werneria*, and *Phrynobatrachus* (Hirschfeld et al. 2016; Doherty-Bone and Gvoždík 2017; Tchassem et al., in press). The causes of these disappearances remain unknown, but the declines on Mount Manengouba and Mount Oku have coincided with an increase in the prevalence of amphibian chytrid fungus (*Batrachochytrium dendrobatidis*, *Bd*), indicating that disease could be a factor (Hirschfeld et al. 2016). The role of climate change in these declines also remains unclear and represents a research gap that requires urgent attention (Doherty-Bone and Gvoždík 2017; Tchassem et al., in press). On Mount Mbam, further research should include investigating the role of fire, which could be a factor, not just from its use by livestock herders but

Table 2. Summary of amphibian species (total per habitat type across all survey techniques) encountered during the present study (2014–2016).

Species	**Pasture-grassland**	**Gallery forest**
Afrixalus aff. *fulvovittatus*	15	1
Astylosternus montanus	5	14
Astylosternus rheophilus	0	5
Hoplobatrachus occipitalis	5	0
Hyperolius balfouri	21	0
Hyperolius tuberculatus	15	0
Hyperolius concolor	22	0
Hyperolius igbettensis	7	2
Hyperolius nitidulus	8	0
Hyperolius cinnamomeoventris	7	0
Leptodactylodon perreti	5	0
Leptopelis nordequatorialis	2	0
Leptopelis notatus	6	5
Phrynobatrachus steindachneri	0	4
Sclerophrys maculata	0	5
Ptychadena mascareniensis "D"	13	0
Xenopus cf. *eysoole*	58	0
Total	189	36
Species richness	14	7
Species evenness	0.86	0.80
Shannon's *D*	3.27	2.44
Mean number of specimens per sampling event	23.63	4.50

Fig. 4. Montane endemic amphibian species observed in recent surveys of Mount Mbam, West-Region, Cameroon. **a)** *Astylosternus rheophilus*, **b)** *Astylosternus montanus*, **c)** *Afrixalus* aff. *fulvovittatus*, **d)** *Hyperolius balfouri*, **e)** *Hyperolius igbettensis*, **f)** *Hyperolius nitidulus*, **g)** *Hyperolius concolor*, **h)** *Hyperolius cinnamomeoventris,* **i)** *Hyperolius tuberculatus*, **j)** *Leptopelis nordequatorialis*, **k)** *Leptopelis boulengeri*, **l)** *Phrynobatrachus steindachneri*, **m)** *Xenopus* cf. *eysoole*, **n)** *Hoplobatrachus occipitalis*, and **o)** *Sclerophrys maculata*.

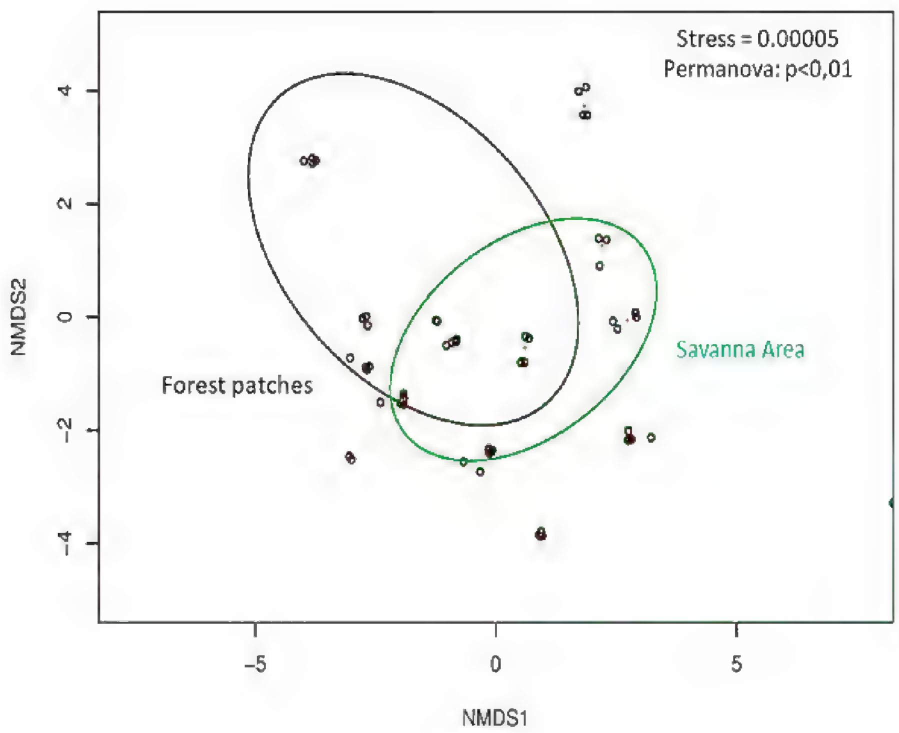

Fig. 5. Non-metric dimensional scaling plot of amphibian community structure divided by land use type on Mount Mbam based on visual encounter surveys with equal effort for each land use. The PERMANOVA p-value is shown in the top right corner.

also its influence by climate change. Some species were possibly overlooked during this study, possibly due to variance in the detectability of rare and/or cryptic species (Mackenzie et al. 2005; Megson et al. 2009); thus, further efforts to continue this study would benefit from complementary survey methods such as pitfall traps and continuous audio recordings. However, it is also possible that the species pool for Mount Mbam has simply been degraded historically.

The presence of livestock grazing on the slopes of Mount Mbam has likely modified the landscape structure of habitats to a great extent, such as through loss of forest from grazing, fires, and trampling by livestock (Carte and John 2002). The remaining forest on Mount Mbam is now reduced to patches along streams and close to the summit where access is difficult for livestock. The historical loss of forest is likely to have negatively affected populations of forest-dependent species, while potentially benefitting tolerant, savanna-adapted species. While the forests hosted fewer species than savanna, those species are montane endemics of conservation concern, while the greater species richness of the savanna consists of species with broader, lowland ranges. Most of the amphibian species were significantly influenced by elevation, habitat, and season. This indicates that despite more savanna becoming available, the colonization by lowland species may remain limited.

Planning and implementing effective strategies to control habitat disturbance and encourage recovery on this mountain could be required to stop further loss of montane endemic species in the long term. Future studies should investigate the precise impacts of bushfire, including influences on nutrient cycling, water quality, predation risk to anurans, and reproductive success. The conservation needs of Mount Mbam are similar to those of Mount Bamboutos, but are driven more by livestock than the cultivation of crops. As with Mount Bamboutos, Mount Mbam has neither official protection nor conservation action, and the exploitation of its resources is unregulated. Several measures could be implemented to reduce the rate of forest loss on Mount Mbam. Steps such as raising environmental awareness, conducting educational seminars, and preparing educational materials for the locals, would certainly have a positive

Table 3. Similarity percentage (SIMPER) analysis showing importance of dissimilarity for various amphibian species for habitat type based on visual encounter surveys of Mount Mbam.

	Mean number of individuals per survey			
Taxon	**Forest**	**Pasture-grassland**	**Contribution to dissimilarity**	**Cumulative contribution**
Xenopus cf. *eysoole*	0 ± 0	0.64 ± 1.24	0.17	0.17
Astylosternus montanus	0.47 ± 0.86	0.06 ± 0.23	0.14	0.32
Leptopelis notatus	0.17 ± 0.42	0.07 ± 0.39	0.08	0.39
Hyperolius balfouri	0 ± 0	0.23 ± 0.75	0.07	0.46
Hyperolius concolor	0 ± 0	0.24 ± 0.96	0.06	0.58
Afrixalus aff. *fulvovittatus*	0.03 ± 0.18	0.17 ± 0.60	0.06	0.52
Astylosternus rheophilus	0.17 ± 0.46	0 ± 0	0.05	0.69
Hyperolius igbettensis	0.07 ± 0.25	0.08 ± 0.37	0.05	0.79
Hyperolius tuberculatus	0 ± 0	0.17 ± 0.64	0.05	0.89
Phrynobatrachus steindachneri	0.13 ± 0.35	0 ± 0	0.05	0.84
Ptychadena mascareniensis	0 ± 0	0.14 ± 0.49	0.05	0.63
Hyperolius cinnamomeoventris	0 ± 0	0.08 ± 0.37	0.03	0.95
Hyperolius nitidulus	0 ± 0	0.09 ± 0.41	0.03	0.92
Sclerophrys maculata	0 ± 0	0.06 ± 0.23	0.03	0.97
Hoplobatrachus occipitalis	0 ± 0	0.06 ± 0.38	0.02	0.99
Leptopelis nordequatorialis	0 ± 0	0.02 ± 0.15	0.01	1

Table 4. Generalized linear models comparing parameters which influence the abundance of amphibian species on Mount Mbam.

Species	Model parameters	df	Residual deviance	*p*-value	AIC	ΔAIC
Afrixalus aff. *fulvovittatus*	Habitat*Elevation*Season	112	41.48	0.99	78	2
	Habitat*Elevation	116	63.52	< 0.01	92	26
	Habitat*Season	116	62.95	<0.001	91	25
	Season*Elevation	116	47.88	<0.001	76	0
	Habitat*Year	116	77.78	0.01	106	30
	Habitat	118	84.83	0.05	109	33
	Elevation	118	74.05	<0.001	98	12
	Season	118	81.87	<0.01	106	30
	Year	112	88.35	0.53	112	36
Astylosternus montanus	Habitat*Elevation*Season	112	51.96	0.99	100	7
	Habitat*Elevation	116	59.92	0.06	100	7
	Habitat*Season	116	56.69	0.99	97	4
	Season*Elevation	116	64.91	0.99	105	8
	Habitat*Year	116	53.47	0.90	93	0
	Habitat	118	64.11	<0.001	100	7
	Elevation	118	75.79	<0.01	112	19
	Season	118	68.49	<0.001	104	11
	Year	118	81.52	0.12	117	24
Astylosternus rheophilus	Habitat*Elevation*Season	112	9.76	0.99	99	7
	Habitat*Elevation	116	9.76	0.99	26	0
	Habitat*Season	116	20.00	0.99	37	11
	Season*Elevation	116	9.92	1	26	0
	Habitat*Year	116	20.51	0.99	37	11
	Habitat	118	20.69	<0.001	33	7
	Elevation	118	9.93	<0.001	58	32
	Season	118	30.50	<0.001	43	17
	Year	118	31.11	0.51	45	19
Hoplobatrachus occipitalis	Habitat*Elevation*Season	112	34.40	1.00	56	13
	Habitat*Elevation	116	35.47	1.00	49	6
	Habitat*Season	116	38.26	0.99	52	9
	Season*Elevation	116	34.65	0.32	48	5
	Habitat*Year	116	29.11	1.00	43	0
	Habitat	118	38.268	0.09	48	5
	Elevation	118	35.64	0.02	45	2
	Season	118	41.05	0.75	50	7
	Year	118	204.44	0.21	269.90	221
Hyperolius balfouri	Habitat*Elevation*Season	112	68.50	0.99	108	29
	Habitat*Elevation	116	90.26	1.00	123	21
	Habitat*Season	116	76.22	0.99	108	6
	Season*Elevation	116	69.92	0.99	102	0
	Habitat*Year	116	99.10	0.99	131	29
	Habitat	118	99.26	<0.001	128	26
	Elevation	118	91.12	<0.001	119	30

Table 4 (Cont.). Generalized linear models comparing parameters which influence the abundance of amphibian species on Mount Mbam.

Species	Model parameters	df	Residual deviance	*p*-value	AIC	ΔAIC
	Season	118	94.31	<0.001	123	21
	Year	118	111.34	0.94	139	36
Hyperolius cinnamomeoventris	Habitat*Elevation*Season	112	39.44	1.00	65	19
	Habitat*Elevation	116	42.10	0.99	60	14
	Habitat*Season	116	44.07	1.00	62	16
	Season*Elevation	116	40.14	0.13	58	12
	Habitat*Year	116	31.24	1.00	49	3
	Habitat	118	44.07	0.04	58	12
	Elevation	118	42.49	0.02	56	10
	Season	118	47.83	0.60	62	16
	Year	118	32.36	<0.001	46	0
Hyperolius concolor	Habitat*Elevation*Season	112	82.19	0.99	119	0
	Habitat*Elevation	116	103.88	0.99	132	13
	Habitat*Season	116	108.83	0.99	137	19
	Season*Elevation	116	100.95	<0.001	129	10
	Habitat*Year	116	116.84	0.99	145	26
	Habitat	118	117.32	<0.001	142	23
	Elevation	118	129.98	0.97	154	35
	Season	118	125.50	0.03	150	31
	Year	118	129.81	0.68	154	35
Hyperolius igbettensis	Habitat*Elevation*Season	112	044.07	0.19	74	2
	Habitat*Elevation	116	53.05	0.36	75	3
	Habitat*Season	116	52.12	0.13	74	2
	Season*Elevation	116	53.54	0.46	75	3
	Habitat*Year	116	54.83	0.81	76	4
	Habitat	118	54.91	0.84	73	1
	Elevation	118	54.30	0.42	72	0
	Season	118	54.46	0.49	72	0
	Year	118	54.93	0.91	73	1
Hyperolius nitidulus	Habitat*Elevation*Season	112	43.35	1.00	71	7
	Habitat*Elevation	116	48.10	0.99	68	4
	Habitat*Season	116	44.71	1.00	64	0
	Season*Elevation	116	46.39	0.30	66	2
	Habitat*Year	116	46.23	0.99	65	1
	Habitat	118	48.10	0.03	64	0
	Elevation	118	50.29	0.12	66	2
	Season	118	50.85	0.17	66	2
	Year	118	49.48	0.07	65	1
Hyperolius tuberculatus	Habitat*Elevation*Season	112	73.36	0.99	106	7
	Habitat*Elevation	116	79.67	0.99	104	5
	Habitat*Season	116	75.91	0.99	100	1
	Season*Elevation	116	74.91	0.33	99	0
	Habitat*Year	116	81.60	0.99	106	7

Table 4 (Cont.). Generalized linear models comparing parameters which influence the abundance of amphibian species on Mount Mbam.

Species	Model parameters	df	Residual deviance	*p*-value	AIC	ΔAIC
	Habitat	118	81.85	<0. 01	103	4
	Elevation	118	80.99	<0.01	101	2
	Season	118	87.32	<0. 01	108	9
	Year	118	90.41	0.79	111	12
Leptodactylodon perreti	Habitat*Elevation*Season	112	14.52	0.99	39	11
	Habitat*Elevation	116	14.54	0.99	31	3
	Habitat*Season	116	20.00	1.00	37	9
	Season*Elevation	116	14.99	0.99	32	4
	Habitat*Year	116	20.51	0.99	37	9
	Habitat	118	20.69	<0.001	33	5
	Elevation	118	15.07	<0.001	28	0
	Season	118	30.49	0.04	43	15
	Year	118	34.12	0.51	46	18
Leptopelis notatus	Habitat*Elevation*Season	112	31.79	0.99	65	14
	Habitat*Elevation	116	43.04	<0.01	69	0
	Habitat*Season	116	48.74	0.01	74	5
	Season*Elevation	116	48.84	<0.01	74	5
	Habitat*Year	116	58.95	0.85	84	14
	Habitat	118	59.78	0.14	81	12
	Elevation	118	61.16	0.38	83	12
	Season	118	59.86	0.15	81	12
	Year	118	60.98	0.33	82	13
Ptychadena mascareniensis "D"	Habitat*Elevation*Season	112	52.10	1.00	88	4
	Habitat*Elevation	116	61.89	0.99	90	6
	Habitat*Season	116	55.95	0.99	84	0
	Season*Elevation	116	58.16	0.28	86	2
	Habitat*Year	116	57.98	0.99	86	2
	Habitat	118	62.44	<0.01	87	3
	Elevation	118	67.71	0.14	90	6
	Season	118	59.56	<0.01	84	0
	Year	118	156	<0.001	90	6
Sclerophrys maculata	Habitat*Elevation*Season	112	27.81	1.00	54	20
	Habitat*Elevation	116	28.90	1.00	57	23
	Habitat*Season	116	28.27	0.99	46	12
	Season*Elevation	116	28.49	0.33	46	12
	Habitat*Year	116	19.74	0.99	38	4
	Habitat	118	28.90	0.09	43	9
	Elevation	118	30.34	0.23	44	10
	Season	118	30.30	0.22	44	10
	Year	118	20.54	<0.001	34	0
Xenopus cf. *eysoole*	Habitat*Elevation*Season*Year	-1	0	1.00	148	103
	Habitat*Elevation*Season	112	151.00	1.00	228	183
	Habitat*Elevation	116	172.00	0.99	241	196

Table 4 (Cont.). Generalized linear models comparing parameters which influence the abundance of amphibian species on Mount Mbam.

Species	Model parameters	df	Residual deviance	*p*-value	AIC	ΔAIC
	Habitat*Season	116	153.46	1.00	223	178
	Season*Elevation	116	160.98	0.008	230	185
	Habitat*Year	116	172.40	1.00	242	197
	Habitat	118	172.65	<0.001	238	193
	Elevation	118	192.65	<0.001	265	220
	Season	118	172.32	<0.001	238	193
	Year	118	204.44	<0.001	45	0

effect on changing negative attitudes. The creation of a protected area for these habitats, with strong involvement of the local people, would be a plausible strategy. The proportion of endangered species of the Mount Mbam is very low, but this does not in any way diminish its importance for the conservation of the endemic amphibian species, whereas the differences observed at low and high altitudes with regard to species composition and habitat type should make this site a national or sub-regional conservation priority.

Acknowledgments.—The authors express their gratitude to the Cameroon Ministry of Scientific Research and Innovation and the Ministry of Forestry and Wildlife for authorizing our fieldwork (permit number 629PRS/MINFOF/SG/DFAP/SDVEF/SC). We especially thank Mark Wilkinson, Natural History Museum, London, United Kingdom for assistance. We thank the Rufford Small Grant (RSG) for funding this work. In addition, we wish to acknowledge the village chiefs and community elders who permitted the work on their land, and thank field assistants Mballa Moussa and Daho. The authors also thank the reviewers for helping to improve this manuscript.

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